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Chen et al.

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(54) **METHODS FOR INTROSPECTING CODE IN A MULTI-TENANT ENVIRONMENT**

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(51) **Int. Cl.**

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G06F 16/242	(2019.01)
G06F 16/28	(2019.01)
G06F 16/2452	(2019.01)
G06F 16/2455	(2019.01)

(52) **U.S. Cl.**
CPC ***G06F 16/24575*** (2019.01); ***G06F 16/2433*** (2019.01); ***G06F 16/24524*** (2019.01); ***G06F 16/24553*** (2019.01); ***G06F 16/288*** (2019.01)

(58) **Field of Classification Search**
CPC G06F 16/24575; G06F 16/2433; G06F 16/24524; G06F 16/24553; G06F 16/288; G06F 16/21; G06F 8/315; G06F 8/75
See application file for complete search history.

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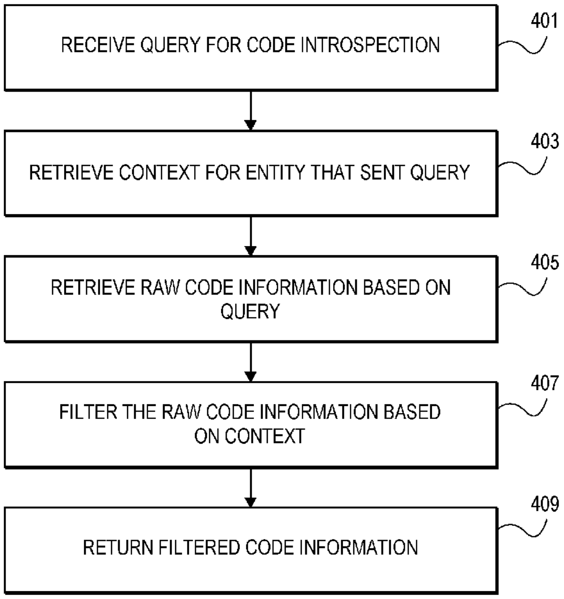
(57) **ABSTRACT**

A method and system for code introspection in a multi-tenant architecture. The method includes receiving a query for code introspection from an entity, retrieving context for the entity that sent the query, retrieving raw code information based on the query, filtering the raw code information based on the context, and returning the filtered code information.

21 Claims, 11 Drawing Sheets


RECEIVE QUERY FOR CODE INTROSPECTION
401
RETRIEVE CONTEXT FOR ENTITY THAT SENT QUERY
403
RETRIEVE RAW CODE INFORMATION BASED ON QUERY
405
FILTER THE RAW CODE INFORMATION BASED ON CONTEXT
407
RETURN FILTERED CODE INFORMATION
409

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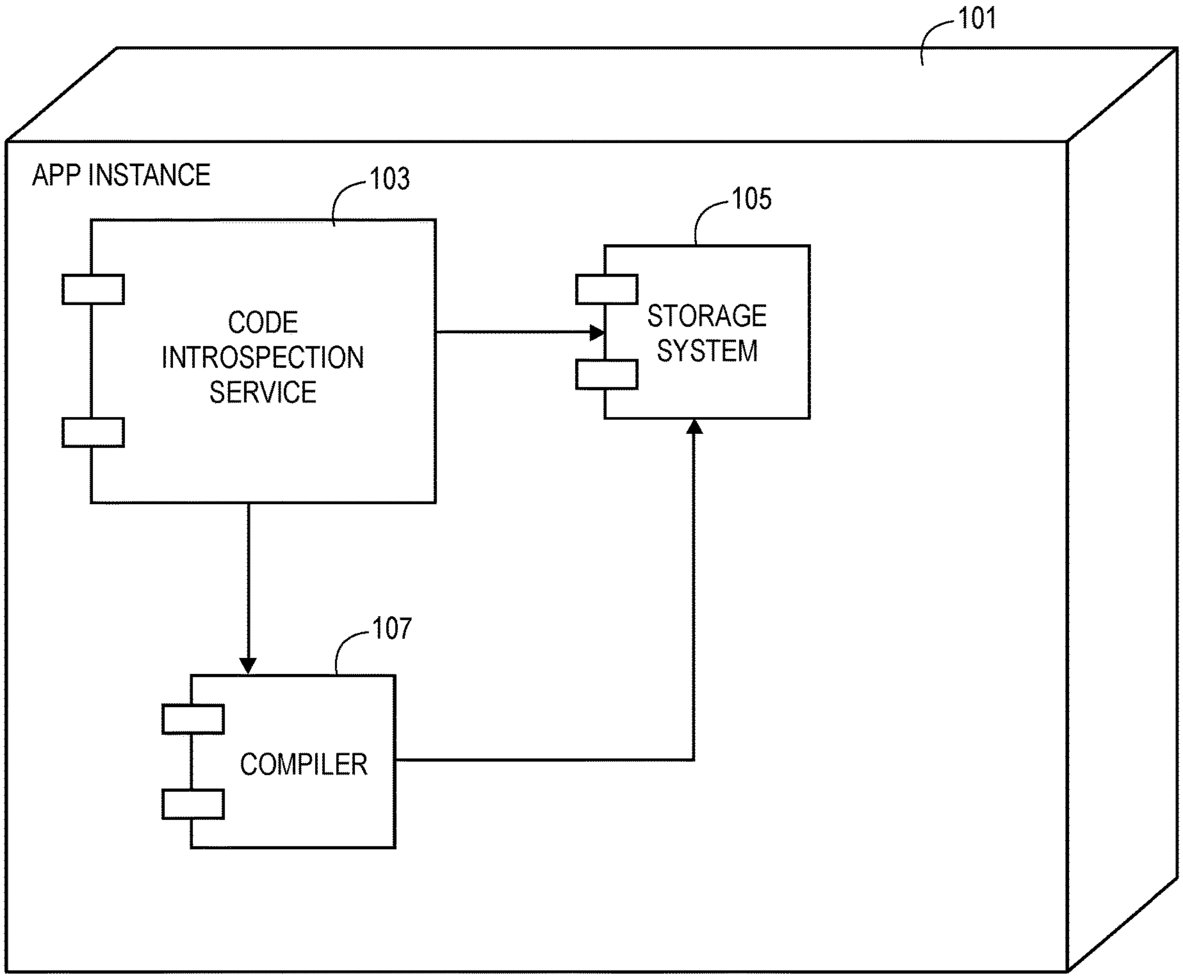

101
APP INSTANCE
103
CODE INTROSPECTION SERVICE
105
STORAGE SYSTEM
107
COMPILER

FIG. 1

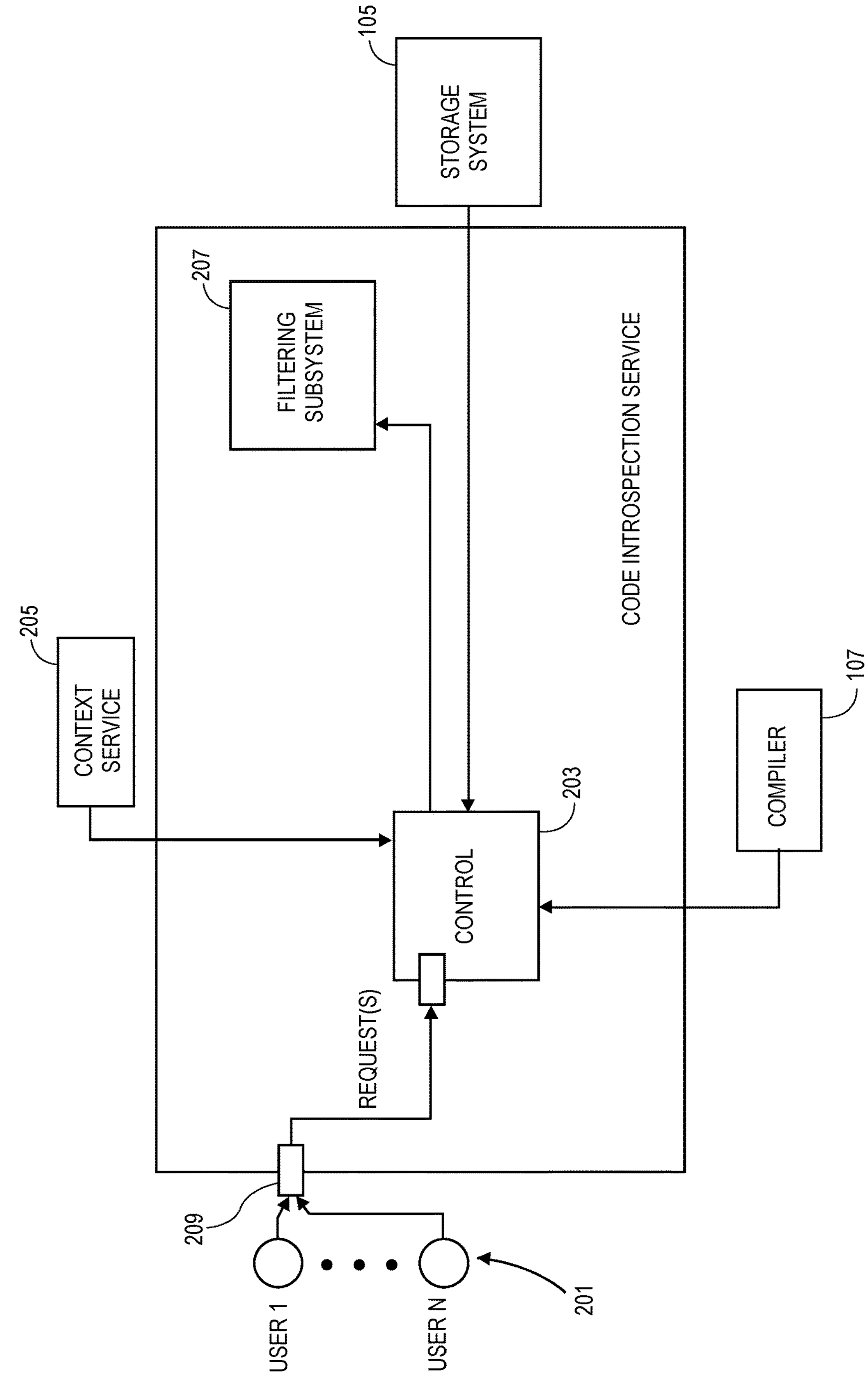

105
STORAGE SYSTEM
207
FILTERING SUBSYSTEM
CODE INTROSPECTION SERVICE
205
CONTEXT SERVICE
203
CONTROL
107
COMPILER
REQUEST(S)
209
USER 1
USER N
201

FIG. 2

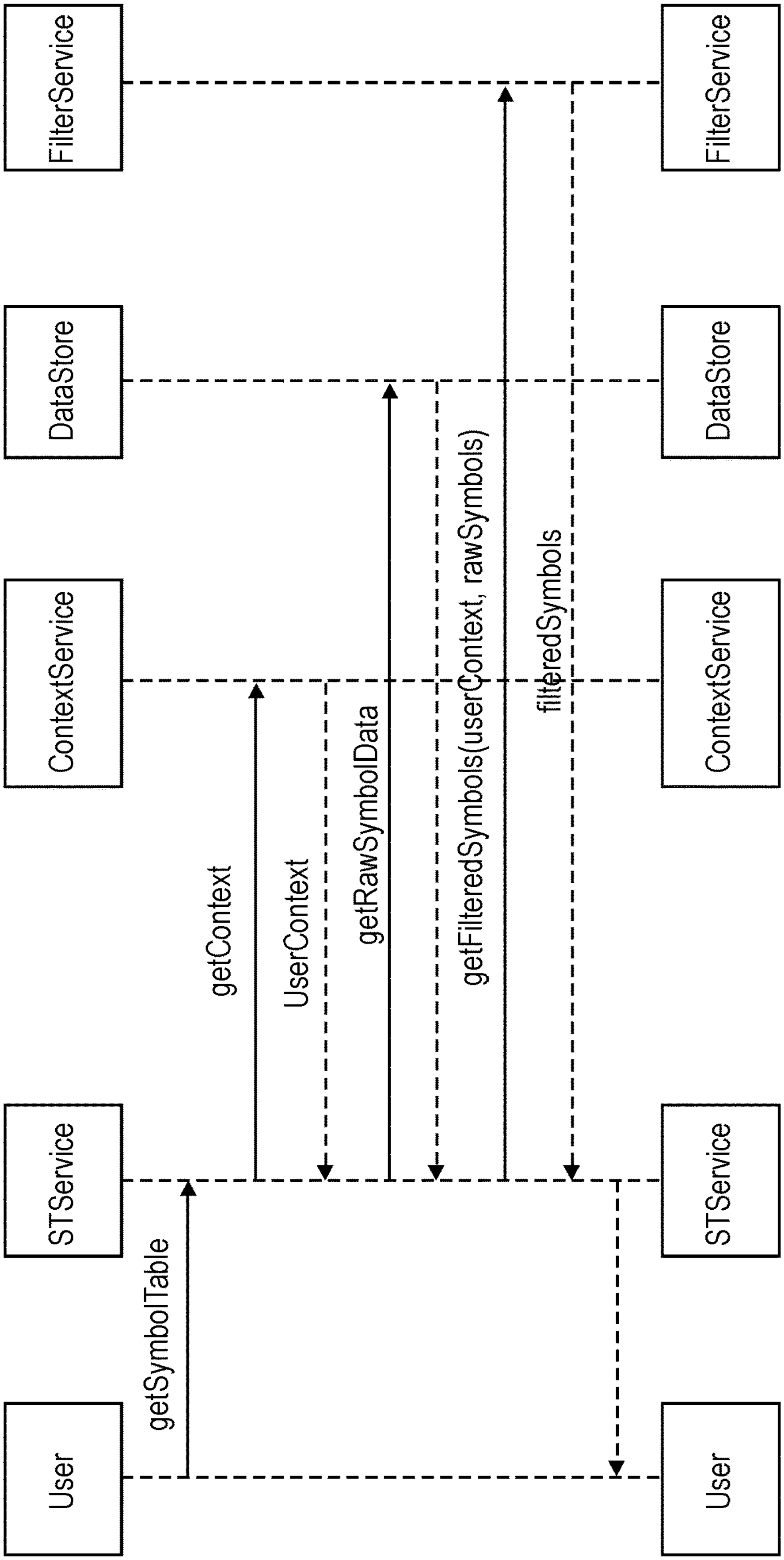

User
STService
ContextService
DataStore
FilterService
getSymbolTable
getContext
UserContext
getRawSymbolData
getFilteredSymbols(userContext, rawSymbols)
filteredSymbols
User
STService
ContextService
DataStore
FilterService

FIG. 3

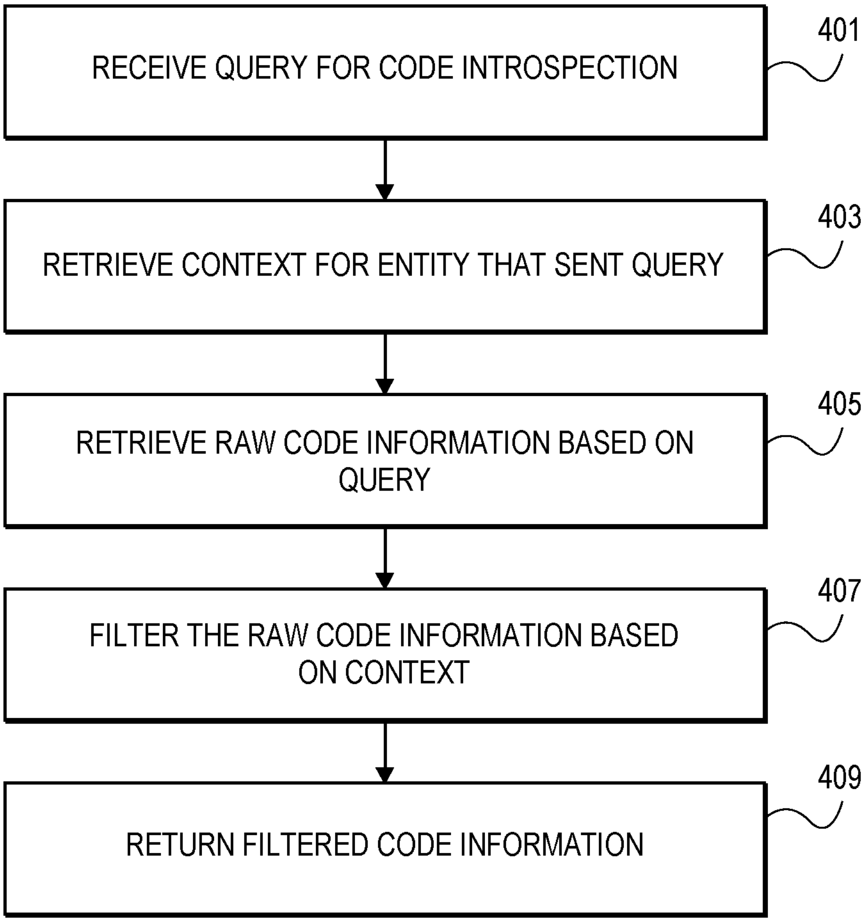
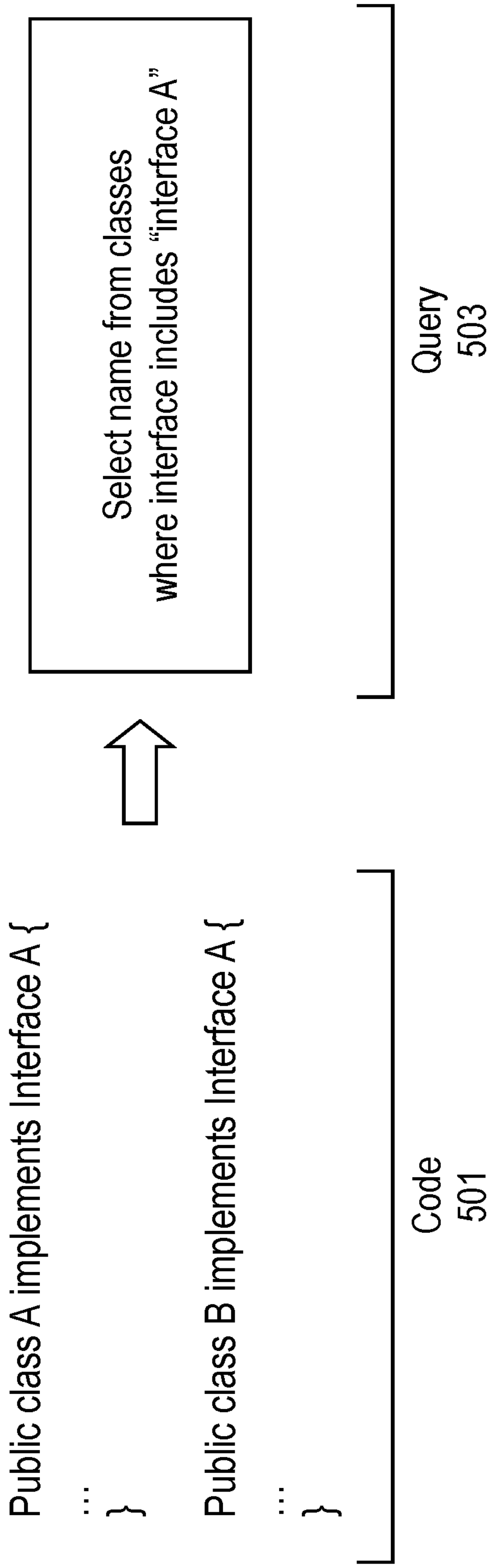

RECEIVE QUERY FOR CODE INTROSPECTION
401
RETRIEVE CONTEXT FOR ENTITY THAT SENT QUERY
403
RETRIEVE RAW CODE INFORMATION BASED ON QUERY
405
FILTER THE RAW CODE INFORMATION BASED ON CONTEXT
407
RETURN FILTERED CODE INFORMATION
409

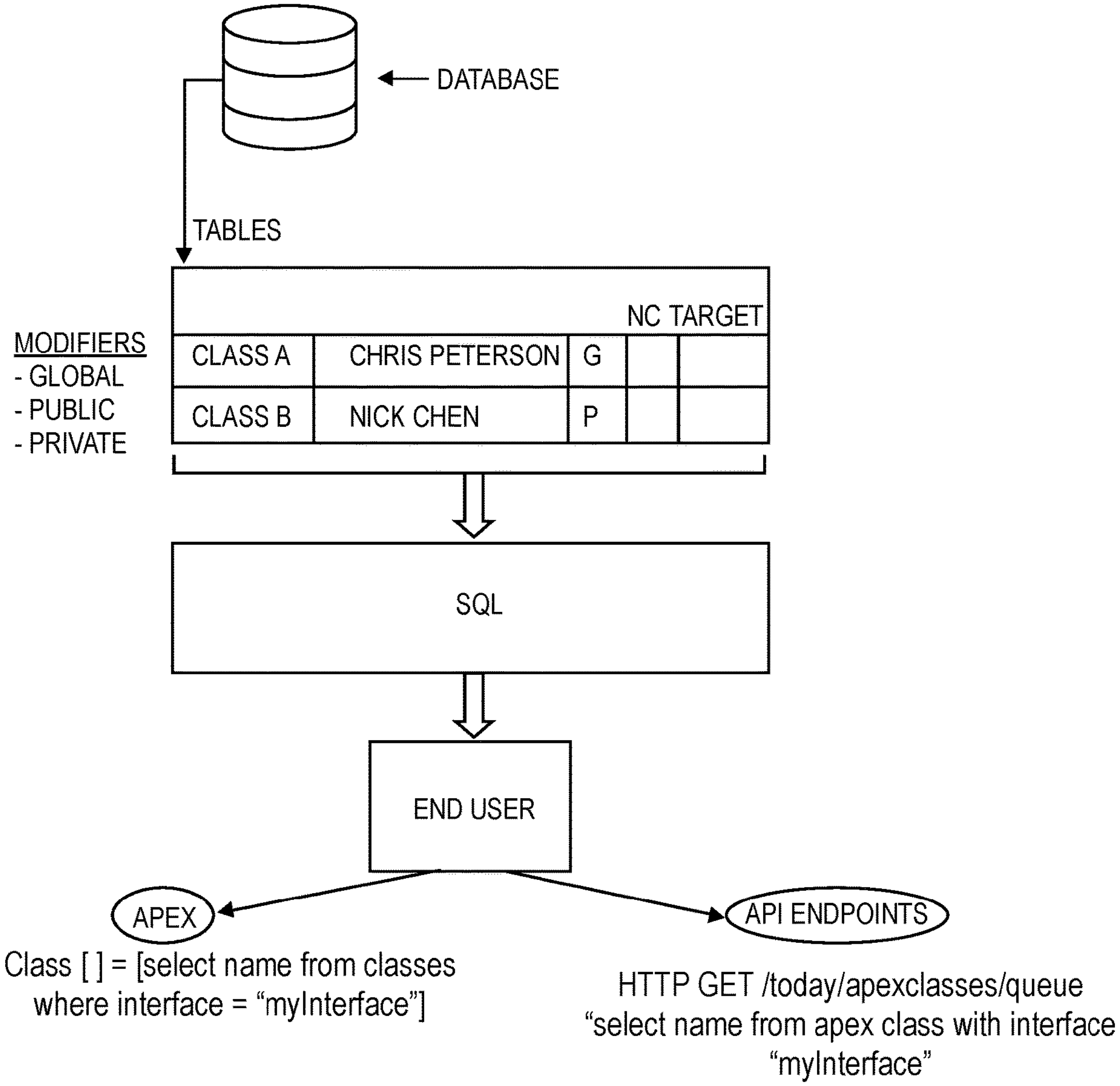
FIG. 4



```
Public class A implements Interface A {
...
}
Public class B implements Interface A {
...
}
```

Select name from classes
where interface includes “interface A”

FIG. 5



				NC TARGET
CLASS A	CHRIS PETERSON	G		
CLASS B	NICK CHEN	P		

Class [ ] = [select name from classes
where interface = “myInterface”]

HTTP GET /today/apexclasses/queue
“select name from apex class with interface
“myInterface”

FIG. 6

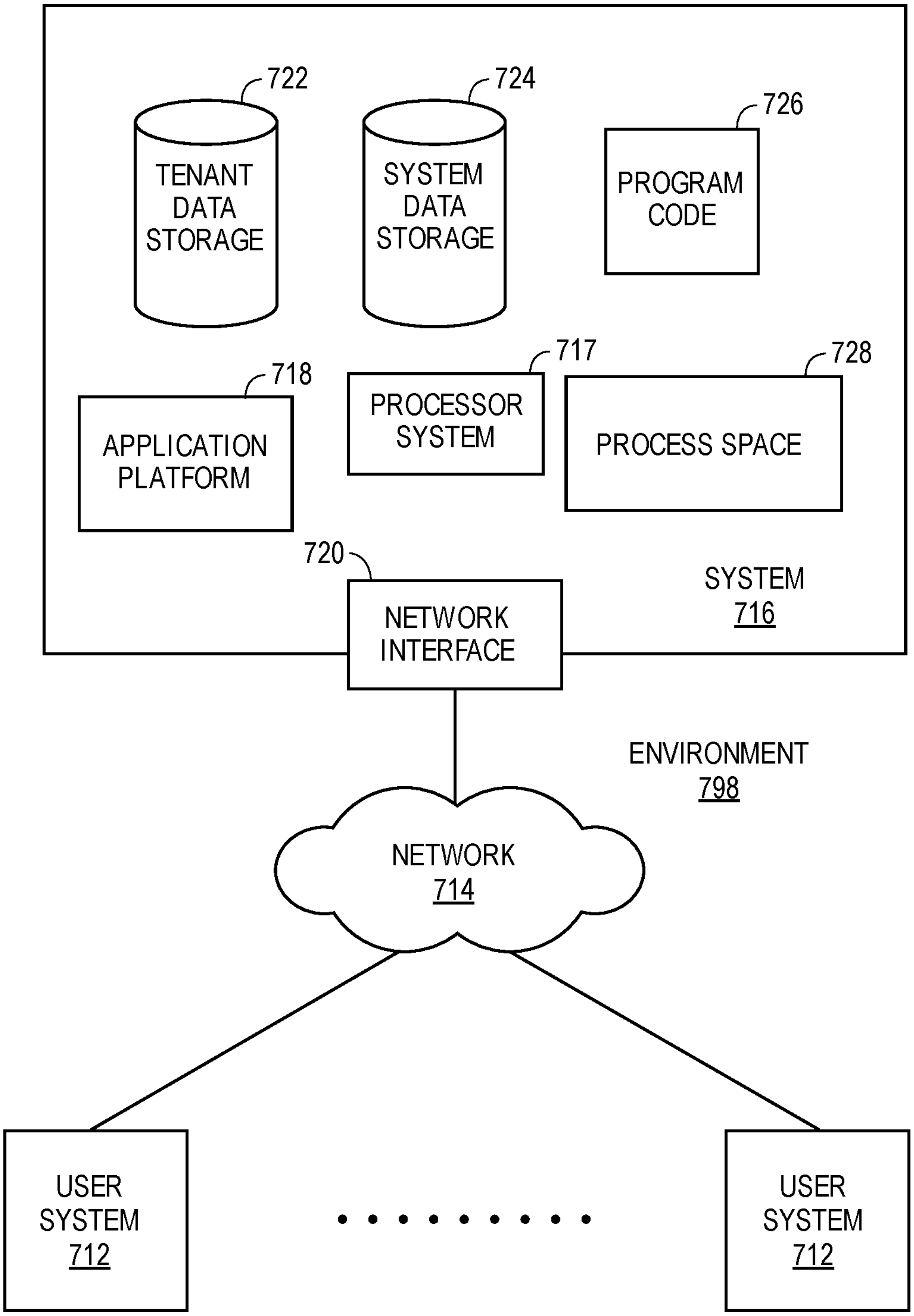

722
TENANT DATA STORAGE
724
SYSTEM DATA STORAGE
726
PROGRAM CODE
717
728
718
PROCESSOR SYSTEM
PROCESS SPACE
APPLICATION PLATFORM
720
NETWORK INTERFACE
SYSTEM 716
ENVIRONMENT 798
NETWORK 714
USER SYSTEM 712
USER SYSTEM 712

FIG. 7

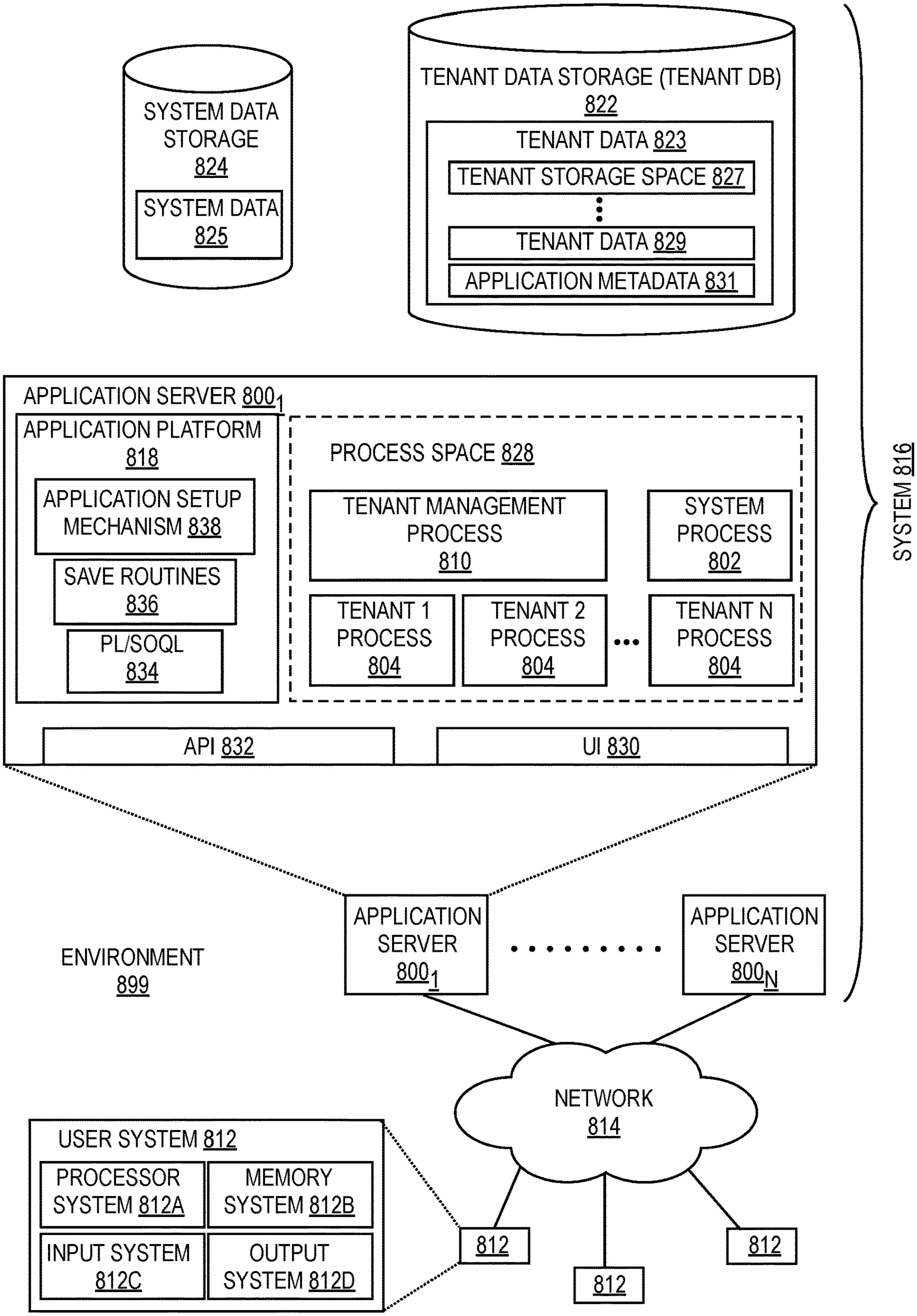

SYSTEM DATA STORAGE 824
SYSTEM DATA 825
TENANT DATA STORAGE (TENANT DB) 822
TENANT DATA 823
TENANT STORAGE SPACE 827
TENANT DATA 829
APPLICATION METADATA 831
SYSTEM 816
APPLICATION SERVER 800_1
APPLICATION PLATFORM 818
APPLICATION SETUP MECHANISM 838
SAVE ROUTINES 836
PL/SOQL 834
PROCESS SPACE 828
TENANT MANAGEMENT PROCESS 810
SYSTEM PROCESS 802
TENANT 1 PROCESS 804
TENANT 2 PROCESS 804
TENANT N PROCESS 804
API 832
UI 830
ENVIRONMENT 899
APPLICATION SERVER 800_1
APPLICATION SERVER 800_N
NETWORK 814
USER SYSTEM 812
PROCESSOR SYSTEM 812A
MEMORY SYSTEM 812B
INPUT SYSTEM 812C
OUTPUT SYSTEM 812D
812
812
812

FIG. 8

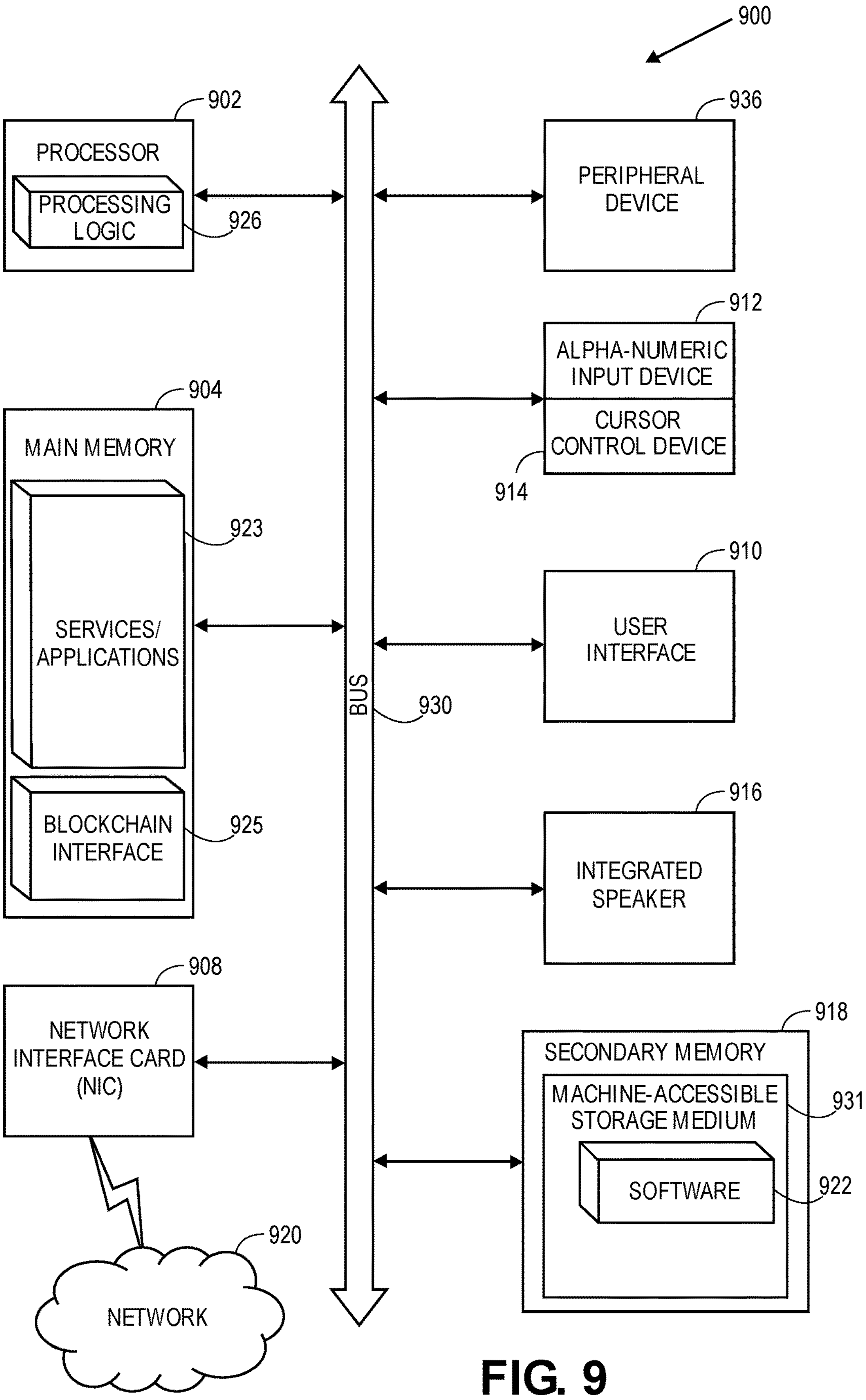

900
902
PROCESSOR
PROCESSING LOGIC
926
904
MAIN MEMORY
923
SERVICES/ APPLICATIONS
BLOCKCHAIN INTERFACE
925
908
NETWORK INTERFACE CARD (NIC)
920
NETWORK
BUS
930
936
PERIPHERAL DEVICE
912
ALPHA-NUMERIC INPUT DEVICE
CURSOR CONTROL DEVICE
914
910
USER INTERFACE
916
INTEGRATED SPEAKER
918
SECONDARY MEMORY
MACHINE-ACCESSIBLE STORAGE MEDIUM
931
SOFTWARE
922

FIG. 9

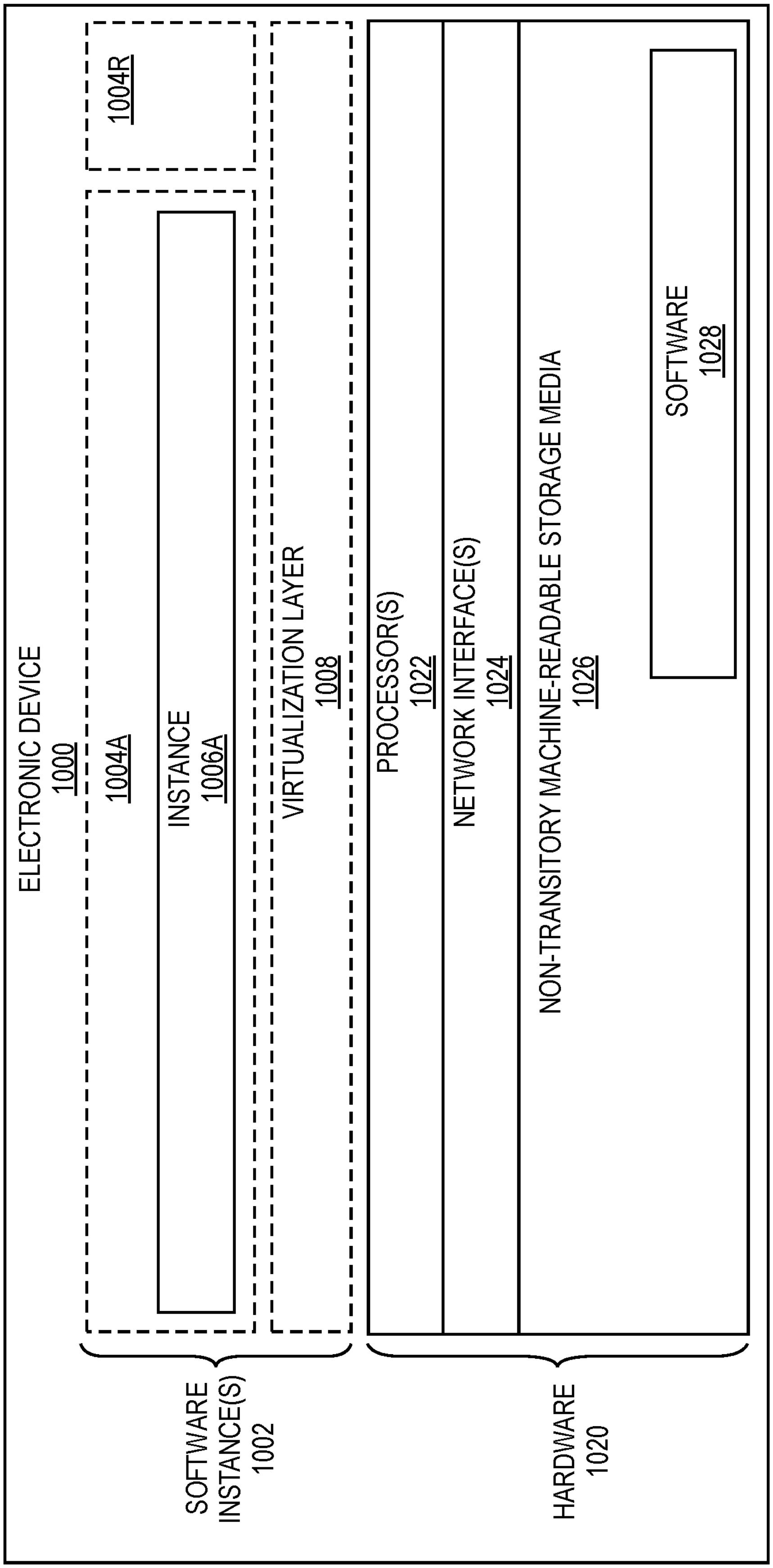

ELECTRONIC DEVICE
1000
1004A
INSTANCE
1006A
1004R
VIRTUALIZATION LAYER
1008
SOFTWARE
INSTANCE(S)
1002
PROCESSOR(S)
1022
NETWORK INTERFACE(S)
1024
NON-TRANSITORY MACHINE-READABLE STORAGE MEDIA
1026
SOFTWARE
1028
HARDWARE
1020

FIG. 10A

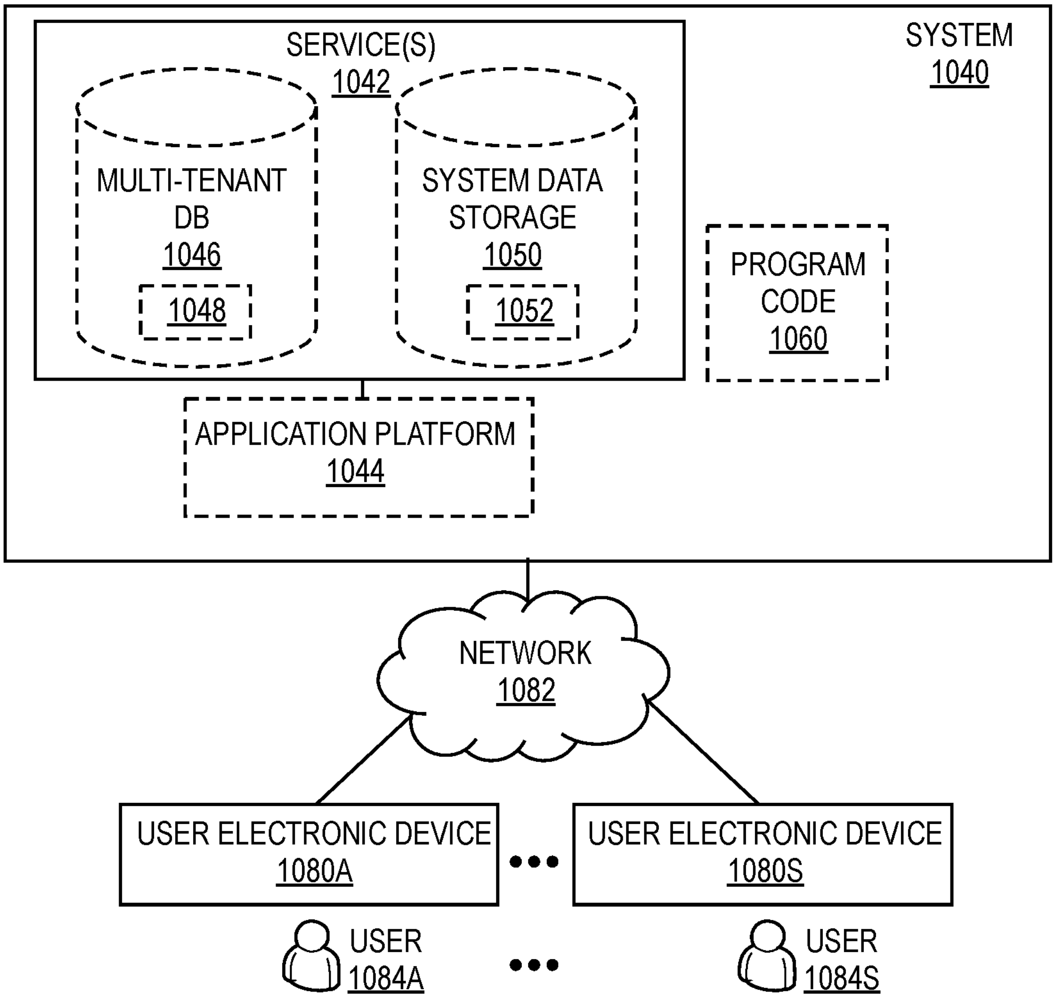

SERVICE(S)
1042
MULTI-TENANT
DB
1046
1048
SYSTEM DATA
STORAGE
1050
1052
SYSTEM
1040
PROGRAM
CODE
1060
APPLICATION PLATFORM
1044
NETWORK
1082
USER ELECTRONIC DEVICE
1080A
USER ELECTRONIC DEVICE
1080S
USER
1084A
USER
1084S

FIG. 10B

METHODS FOR INTROSPECTING CODE IN A MULTI-TENANT ENVIRONMENT

TECHNICAL FIELD

One or more implementations relate to the field of code introspection and reflection; and more specifically, to methods and system for code introspection and reflection in a multi-tenant environment.

BACKGROUND ART

One A multi-tenant system is a shared computing system. The multi-tenant system provides software multitenancy, which refers to a software architecture in which a single instance of a software application runs on a server and serves multiple tenants, where the "tenants" are different organizations, or subscribers to the application or the multi-tenant system. Each organization or subscriber can be associated with a set of users that can access the software application. The users of the software application can access data specific to the user or the organization of the user, but the software application is designed to prevent users to access the data of other organizations or subscribers. The multi-tenant system and the software application can enforce sets of privileges specific to tenants, organizations, subscribers, and/or users.

Multi-tenant systems can be considered shared systems (in contrast to dedicated or isolated system). Thus, with a multitenant architecture, a software application is designed to provide every tenant a dedicated share of the instance of the software application including data, configuration, user management, tenant individual functionality, and similar features and properties. Multitenancy contrasts with multi-instance architectures, where separate software instances operate on behalf of different tenants.

Software applications are developed and deployed into multi-tenant architectures. However, often the tools and features of computing programming languages and software developing environments are not adapted for or designed for use in multi-tenant environments. Thus, developing, testing, and deploying software applications in multi-tenant environments can be more challenging than in dedicated or isolated systems where there is no need to support multiple tenants using the software application and supporting the associated varied privileges associated with different tenants, organizations, subscribers and users.

BRIEF DESCRIPTION OF THE DRAWINGS

The following figures use like reference numbers to refer to like elements. Although the following figures depict various exemplary implementations, alternative implementations are within the spirit and scope of the appended claims. In the drawings:

FIG. **1** is a diagram of an application with a code introspection service according to some example implementations.

FIG. **2** is a diagram of a code introspection service according to some example implementations.

FIG. **3** is a diagram of the function calls related to a code introspection service according to some example implementations.

FIG. **4** is a flowchart of a process for code introspection in a multi-tenant system according to some example implementations.

FIG. **5** is a diagram of one implementation of an example set of classes according to some example implementations.

FIG. **6** is a diagram of one implementation of an example query execution according to some example implementations.

FIG. **7** is a diagram of an execution environment according to some example implementations.

FIG. **8** is a diagram of multi-tenant architecture according to some example implementations.

FIG. **9** is a diagram of an electronic device according to some example implementations.

FIG. **10**A is a block diagram illustrating an electronic device according to some example implementations.

FIG. **10**B is a block diagram of an environment where a code introspection service may be deployed, according to some implementations.

DETAILED DESCRIPTION

The following description describes methods and apparatus for code introspection in a multi-tenant architecture. The implementations provide a code introspection service that enables a program or user to submit a query to a database of code information that can locate and retrieve code based on the query expressed in a query language. The results of the query can be filtered based on the permissions of the requesting entity to ensure that the requestor does not aspect code information without appropriate permission.

The term "user" is a generic term referring to an entity (e.g., an individual person) using a system and/or service. A multi-tenant architecture provides each tenant with a dedicated share of a software instance and the ability (typically) to input tenant specific data for user management, tenant-specific functionality, configuration, customizations, non-functional properties, associated applications, etc. Multi-tenancy contrasts with multi-instance architectures, where separate software instances operate on behalf of different tenants. A tenant includes a group of users who share a common access with specific privileges to a software instance providing a service. A tenant may be an organization (e.g., a company, department within a company, etc.). A tenant may have one or more roles relative to a system and/or service. For example, in the context of a customer relationship management (CRM) system or service, a tenant may be a vendor using the CRM system or service to manage information the tenant has regarding one or more customers of the vendor. As another example, in the context of Data as a Service (DAAS), one set of tenants may be vendors providing data and another set of tenants may be customers of different ones or all of the vendors' data. As another example, in the context of Platform as a Service (PAAS), one set of tenants may be third party application developers providing applications/services and another set of tenants may be customers of different ones or all of the third-party application developers. A user may have one or more roles relative to a system and/or service. To provide some examples, a user may be a representative (sometimes referred to as an "end user") of a tenant (e.g., a vendor or customer), a representative (e.g., an administrator) of the company providing the system and/or service, and/or a representative (e.g., a programmer) of a third-party application developer that is creating and maintaining an application(s) on a Platform as a Service (PAAS).

FIG. **1** is a diagram of an application with a code introspection service according to some example implementations. The code introspection service **103** is a service that is incorporated or called by an application instance **101**. The application instance **101** can be any application developed for a multi-tenant architecture. The application instance **101** is an application that is shared by tenants of the multi-tenant architecture. While the application instance **101** is shared by the tenants of the multi-tenant architecture, the storage system **105** and data therein is not shared by the tenants. The code introspection service **103** interfaces with the storage system **105** and/or the compiler **107** to service requests from users of the application instance **101** including user program execution, user command line input, and similar mechanisms by which the user can submit a code inspection query to the code introspection service.

The storage system **105** can be any type of storage system including a database storage system, file system, or similar data storage system. Database systems can include relational database systems, object oriented database systems, and similar database systems, the storage system **105** can be a separate application or set of applications (e.g., database management systems) that operate in the multi-tenant architecture and are accessible via function calls, service, application programming interface (API), or similar mechanism that is embedded within an application instance **101** or accessible to the application instance.

The compiler **107** can be any type of compiler to process tenant code to be executed within or in conjunction with the application instance. The compiler can be a compiler for Apex (by Salseforce.com), Java, C++, or similar programming language. These languages can be used to created modules, add-ins, functions, methods, or other programming components that can be used in conjunction with the application instance **101** to augment the functionality of the application instance **101**. The implementations provide support for code introspection or reflection in these programming components. As used herein 'code introspection' is the ability of a function, command, or program to examine the type or properties of other code (e.g., object code) during runtime execution. Similarly, 'code reflection' as used herein refers to the ability of a function, command, or program to modify the values, metadata, functions, or other properties of other code (e.g., object code) during runtime execution. The implementations are described with relation to supporting code introspection in a multi-tenant architecture. However, one skilled in the art would understand that the principles, functions, and structures described herein with relation to code introspection can also be applied to code reflection implementations.

The application instance **101** can utilize any number or variety of compilers **107**. For sake of clarity and conciseness, the implementations are described with relation to an application instance working in conjunction with a single compiler **107**. However, the processes described herein are also applicable for use with multiple different compilers or similar processes. The compiler **107** can provide the code information that is utilized by the code introspection service **103** to enable code introspection. The compiler **107** can generate a symbol table, abstract syntax tree, and similar code information during the processing of tenant code that is stored partially or entirely within the storage system **105** for subsequent use by the code introspection service. In this manner, the code information collected and stored about each program, module, function, or application, in the multi-tenant architecture can be standardized and made accessible to the cod introspection service.

The code introspection service **103** is a set of function, modules, an API, or similar interface or program to receive requests from the application instance **101** or tenant functions, modules, or programs for code information. For example, a request can be received to identify all classes of module that implement a specific interface. The code introspection service **103** can search the code information in the storage system to identify the code that matches the parameters of a request. In this example, the code introspection service **103** can search for classes that implement the identified interface.

FIG. **2** is a diagram of a code introspection service according to some example implementations. The operation of the code inspection service **103** and its components are illustrated. The code inspection service **103** includes a controller **203** and filtering subsystem **207**. The code inspection service **103** interfaces with storage system **105**, compiler **107**, and context service **205**. The code inspection service receives requests from users **201** via in interface **209**. The components of the code introspection service **103** are provided by way of example and not limitation. One skilled in the art would understand that the functions of the code introspection service can be organized into different combinations of components and that the code introspection service **103** components are provided by way of example to illustrate the operation of the code introspection service **103**.

The code introspection service **103** can service any number of users **209** of an associated application instance. The users **209** can call the code introspection service or send a request to the code introspection service **103** via any type of interface **209**. The calls or requests of the user **209** can originate via any user interface or via any function calls in programs associated with the users **203**. Each user **203** is in turn associated with a tenant and/or organization that subscribe to the multi-tenant architecture. The request can have any format and can be received using any protocol. The requests can provide any criteria or set of parameters to identify code information to be returned to the respective users **209**. For example, the requests can be in the form of a query using any query language, where the query provides the parameters of the search of the code information.

The requests are received via the interface **209** and provided to the controller **203**. The controller parses or similarly processes the request to identify the search terms or query and the user. The controller **203** accesses a context service to obtain permissions information for the user, as well as the organization and/or tenant with which the user is associated. The context service **205** can be accessed using an API or any similar interface. The context service **205** is provided by the multi-tenant architecture, which maintains permissions information for each user, organization, and tenant.

The controller **203** can also search previously compiled code information in the storage system **105** or request that a compiler **107** process relevant code to obtain code information that can be searched using the parameters of the received query. The code information that is provided by the compiler **107** and/or the storage system **105** can have any format or organization. The code information can be symbol tables and/or ASTs for the related code that is generated by the compiler **107** and stored or cached by the multi-tenant architecture in the storage system **105**. The code information that matches the parameters of the search or query is returned to the controller **203** by the storage system **105** and/or the compiler **107**.

The controller provides the context information (i.e., permissions information associated with the user that sent the request) and the code information to a filtering subsystem **207**. The filtering subsystem identifies code information that the user does not have permission to access. All code information is associated with as set of permissions, owners, access controls, or similar information. The context information of the user is utilized to filter the returned code information to remove that code information, which the user does not have permission to access, thereby enforcing the permissions scheme of the multi-tenant architecture. The filtered code information is then returned by the filtering subsystem **207** to the controller **203**, which in turn prepares a response to the received request with the filtered code information or similarly returns the filtered code information to the user **201** that requested this code information.

FIG. **3** is a diagram of the function calls related to an example code introspection service according to some example implementations. In the example of FIG. **3**, the code introspection service is a symbol table service (STService), where the code information in this example system is in the form of symbol tables. In this example, a user calls a getSymbolTable function of the STService, which includes the parameters of the query that a user is requesting. The query is in a query language that defines the parameters of the request.

The STService calls a getContext function of the Context Service. The getContext function includes parameters identifying a user, organization, or tenant of the multi-tenant architecture. The Context Service returns the user context information (i.e., the permissions associated with the user/organization/tenant). The context information can in some cases include other information including API version associated with the user, metadata associated with the user, organization, or tenant, and similar information. The STService also calls a getRawSymbolData function that searches the data storage system (DataStore) and/or calls the compiler to obtain the relevant symbol tables that match the parameters of the received query. The data store and/or compiler returns the requested symbol tables to the STService.

The STService calls the filtering service to apply the permissions of the user context to the raw symbol tables. The function call can receive the user context and the raw symbol table information or identifier as parameters. The filtering service can be implemented in the data store in some implementations to enhance security such that the raw symbol table data does not leave the data storage and cannot be accessed until filtered. Implementing the filtering service in the data store can also enhance performance in some configurations by limiting the amount of data that has to be returned to the STService.

FIG. **4** is a flowchart of a process for code introspection in a multi-tenant system according to some example implementations. The example implementation of FIG. **4** is more general to the operation of a code introspection service in a multi-tenant architecture, in comparison to the specific example of FIG. **3**. In this implementation, the code introspection service operates in response to receiving a query for code introspection from a requesting entity (e.g., a user via a user interface, a function call of an API in a user program, or similar entity in the multi-tenant architecture) (Block **401**). The code introspection service then retrieves content for the requesting entity that specifies the permissions for code access associated with the entity (Block **403**). The context can be retrieved from a separate context service, by searching a database or similar storage system for permissions related to the entity, or by a similar mechanism.

Subsequently or in parallel with obtaining the context information, the code introspection service can obtain raw code information based on the received query (Block **405**). The raw code information can be obtained by submitting the query to a database management system or similar data storage system to identify the aspects of the raw code information (e.g., symbol tables, ASTs, or similar descriptive information about the characteristics of code). The code information is 'raw' in the sense that is has not been filtered or processed to enforce multi-tenant architecture constraints on data access for tenants. The raw code information is then processed to apply the permissions defined by the context information for the requesting entity (Block **407**). Once the code information system has been filtered according to all of the permissions associated with the requesting user, then the filtered code information can be returned to the requesting entity (Block **409**).

FIG. **5** is a diagram of one set of classes and a query according to some example implementations. In the illustrated example, the compiled code **501** in the data storage includes two classes, A and B, which are described as public classes that each implement an interface A. Associated symbol table or AST information describing these classes is stored in the data storage system. A user can submit an example query **503** to request classes that implement the 'interface A.' Both of the classes implement the interface A and could be returned to the requestor.

FIG. **6** is a diagram of a query execution according to some example implementations. In the example of FIG. **6**, the symbol tables for classes A and B are stored in the data storage system, which in this example case is a relational database managed by a relational database management system. The symbol table data stored in the relational database include a name of each class (e.g., classes A and B), owner/user, and permission modifiers (e.g., global, public, private) and similar information. In some embodiments, the class information can be further described to include field information, method, variables, and similar information and metadata. A global modifier would allow any tenant visibility to the class information. Similarly, a public modifier would enable other tenants and user to access the class information. However, a private modifier would deny access to other tenants.

In this example, the submitted query is a structured query language (SQL) query that returns the public class information for Class A, but not the private class information for Class B. This information is returned to the end user whether called via function in user code as handled by a compiler like Apex, or where the end user accesses the code introspection service via API endpoints.

FIG. **7** is a block diagram of an environment in which an on-demand database service may operate in accordance with the described implementations. Environment **798** may include user systems **712**, network **714**, system **716**, processor system **717**, application platform **718**, network interface **720**, tenant data storage **722**, system data storage **724**, program code **726**, and process space **728**. In other implementations, environment **798** may not have all of the components listed and/or may have other elements instead of, or in addition to, those listed above.

Environment **798** is an environment in which an on-demand database service exists. User system **712** may be any machine or system that is used by a user to access a database user system. For example, any of user systems **712** may be a handheld computing device, a mobile phone, a laptop computer, a workstation, and/or a network of computing devices. As illustrated in FIG. **7** (and in more detail in FIG. **8**) user systems **712** might interact via a network **714** with an on-demand database service, which is system **716**.

An on-demand database service, such as system **716**, is a database system that is made available to outside users that do not need to necessarily be concerned with building and/or maintaining the database system, but instead may be available for their use when the users need the database system (e.g., on the demand of the users). Some on-demand database services may store information from one or more tenants stored into tables of a common database image to form a multi-tenant database system (MTS). Accordingly, "on-demand database service **716**" and "system **716**" is used interchangeably herein. A database image may include one or more database objects. A relational database management system (RDMS) or the equivalent may execute storage and retrieval of information against the database object(s). Application platform **718** may be a framework that allows the applications of system **716** to run, such as the hardware and/or software, e.g., the operating system. In an implementation, on-demand database service **716** may include an application platform **718** that enables creation, managing and executing one or more applications developed by the provider of the on-demand database service, users accessing the on-demand database service via user systems **712**, or third party application developers accessing the on-demand database service via user systems **712**.

The users of user systems **712** may differ in their respective capacities, and the capacity of a particular user system **712** might be entirely determined by permissions (permission levels) for the current user. For example, where a salesperson is using a particular user system **712** to interact with system **716**, that user system has the capacities allotted to that salesperson. However, while an administrator is using that user system to interact with system **716**, that user system has the capacities allotted to that administrator. In systems with a hierarchical role model, users at one permission level may have access to applications, data, and database information accessible by a lower permission level user, but may not have access to certain applications, database information, and data accessible by a user at a higher permission level. Thus, different users will have different capabilities with regard to accessing and modifying application and database information, depending on a user's security or permission level.

Network **714** is any network or combination of networks of devices that communicate with one another. For example, network **714** may be any one or any combination of a LAN (local area network), WAN (wide area network), telephone network, wireless network, point-to-point network, star network, token ring network, hub network, or other appropriate configuration. As the most common type of computer network in current use is a TCP/IP (Transfer Control Protocol and Internet Protocol) network, such as the global internetwork of networks often referred to as the "Internet" with a capital "I," that network will be used in many of the examples herein. However, it is understood that the networks that the claimed implementations may utilize are not so limited, although TCP/IP is a frequently implemented protocol.

User systems **712** might communicate with system **716** using TCP/IP and, at a higher network level, use other common Internet protocols to communicate, such as HTTP, FTP, AFS, WAP, etc. In an example where HTTP is used, user system **712** might include an HTTP client commonly referred to as a "browser" for sending and receiving HTTP messages to and from an HTTP server at system **716**. Such an HTTP server might be implemented as the sole network interface between system **716** and network **714**, but other techniques might be used as well or instead. In some implementations, the interface between system **716** and network **714** includes load sharing functionality, such as round-robin HTTP request distributors to balance loads and distribute incoming HTTP requests evenly over a plurality of servers. At least as for the users that are accessing that server, each of the plurality of servers has access to the MTS' data; however, other alternative configurations may be used instead.

In one implementation, system **716**, shown in FIG. **7**, implements a verification system. For example, in one implementation, system **716** includes application servers configured to implement and execute verification services software applications as well as provide related data, code, forms, webpages and other information to and from user systems **712** and to store to, and retrieve from, a database system related data, objects, and Webpage content. With a multi-tenant system, data for multiple tenants may be stored in the same physical database object, however, tenant data typically is arranged so that data of one tenant is kept logically separate from that of other tenants so that one tenant does not have access to another tenant's data, unless such data is expressly shared. In certain implementations, system **716** implements applications other than, or in addition to, verification services. For example, system **716** may provide tenant access to multiple hosted (standard and custom) applications, including verification services application. User (or third party developer) applications, which may or may not include verification services, may be supported by the application platform **718**, which manages creation, storage of the applications into one or more database objects and executing of the applications in a virtual machine in the process space of the system **716**.

One arrangement for elements of system **716** is shown in FIG. **7**, including a network interface **720**, application platform **718**, tenant data storage **722** for tenant data **723**, system data storage **724** for system data **725** accessible to system **716** and possibly multiple tenants, program code **726** for implementing various functions of system **716**, and a process space **728** for executing MTS system processes and tenant-specific processes, such as running applications as part of an application hosting service. Additional processes that may execute on system **716** include database indexing processes.

Several elements in the system shown in FIG. **7** include conventional, well-known elements that are explained only briefly here. For example, each user system **712** may include a desktop personal computer, workstation, laptop, PDA, cell phone, or any wireless access protocol (WAP) enabled device or any other computing device capable of interfacing directly or indirectly to the Internet or other network connection. User system **712** typically runs an HTTP client, e.g., a browsing program, such as Microsoft's Internet Explorer browser, a Mozilla or Firefox browser, an Opera, or a WAP-enabled browser in the case of a smartphone, tablet, PDA or other wireless device, or the like, allowing a user (e.g., subscriber of the multi-tenant database system) of user system **712** to access, process and view information, pages and applications available to it from system **716** over network **714**. Each user system **712** also typically includes one or more user interface devices, such as a keyboard, a mouse, trackball, touch pad, touch screen, pen or the like, for interacting with a graphical user interface (GUI) provided by the browser on a display (e.g., a monitor screen, LCD display, etc.) in conjunction with pages, forms, applications and other information provided by system **716** or other systems or servers. For example, the user interface device may be used to access data and applications hosted by system **716**, and to perform searches on stored data, and otherwise allows a user to interact with various GUI pages that may be presented to a user. As discussed above, implementations are suitable for use with the Internet, which refers to a specific global internetwork of networks. However, it is understood that other networks may be used instead of the Internet, such as an intranet, an extranet, a virtual private network (VPN), a non-TCP/IP based network, any LAN or WAN or the like.

According to one implementation, each user system **712** and all of its components are operator configurable using applications, such as a browser, including computer code run using a central processing unit such as an Intel, ARM, or AMD processor or the like. Similarly, system **716** (and additional instances of an MTS, where more than one is present) and all of their components might be operator configurable using application(s) including computer code to run using a central processing unit such as processor system **717**, which may include an Intel, ARM, or AMD processor or the like, and/or multiple processor units.

According to one implementation, each system **716** is configured to provide webpages, forms, applications, data, and media content to user (client) systems **712** to support the access by user systems **812** as tenants of system **816**. As such, system **816** provides security mechanisms to keep each tenant's data separate unless the data is shared. If more than one MTS is used, they may be located in close proximity to one another (e.g., in a server farm located in a single building or campus), or they may be distributed at locations remote from one another (e.g., one or more servers located in city A and one or more servers located in city B). As used herein, each MTS may include one or more logically and/or physically connected servers distributed locally or across one or more geographic locations. Additionally, the term "server" is meant to include a computer system, including processing hardware and process space(s), and an associated storage system and database application (e.g., OODBMS or RDBMS) as is well known in the art. It is understood that "server system" and "server" are often used interchangeably herein. Similarly, the database object described herein may be implemented as single databases, a distributed database, a collection of distributed databases, a database with redundant online or offline backups or other redundancies, etc., and might include a distributed database or storage network and associated processing intelligence.

FIG. **8** is another block diagram of an environment in which an on-demand database service may operate in accordance with the described implementations. User system **812** may include a processor system **812**A, memory system **812**B, input system **812**C, and output system **812**D. FIG. **9** shows network **814** and system **816**. FIG. **8** also shows that system **816** may include tenant data storage **822**, having therein tenant data **823**, which includes, for example, tenant storage space **827**, tenant data **829**, and application metadata **831**. System data storage **824** is depicted as having therein system data **825**. Further depicted within the expanded detail of application servers **800**$_{1-N}$ are User Interface (UI) **830**, Application Program Interface (API) **832**, application platform **818** includes PL/SOQL **834**, save routines **836**, application setup mechanism **838**, process space **828** includes system process space **802**, tenant **1**-N process spaces **804**, and tenant management process space **810**. In other implementations, environment **899** may not have the same elements as those listed above and/or may have other elements instead of, or in addition to, those listed above.

User system **812**, network **814**, system **816**, tenant data storage **822**, and system data storage **824** were discussed above in FIG. **7**. As shown by FIG. **8**, system **816** may include a network interface **820** implemented as a set of HTTP application servers **800**, an application platform **818**, tenant data storage **822**, and system data storage **824**. Also shown is system process space **802**, including individual tenant process spaces **804** and a tenant management process space **810**. Each application server **800** may be configured to tenant data storage **822** and the tenant data **823** therein, and system data storage **824** and the system data **825** therein to serve requests of user systems **812**. The tenant data **823** might be divided into individual tenant storage areas (e.g., tenant storage space **827**), which may be either a physical arrangement and/or a logical arrangement of data. Within each tenant storage space **827**, tenant data **829**, and application metadata **831** might be similarly allocated for each user. For example, a copy of a user's most recently used (MRU) items might be stored to tenant data **829**. Similarly, a copy of MRU items for an entire organization that is a tenant might be stored to tenant storage space **827**. A UI **830** provides a user interface and an API **832** provides an application programmer interface into system **816** resident processes to users and/or developers at user systems **812**. The tenant data and the system data may be stored in various databases, such as one or more Oracle™ databases.

Application platform **818** includes an application setup mechanism **838** that supports application developers' creation and management of applications, which may be saved as metadata into tenant data storage **822** by save routines **836** for execution by subscribers as one or more tenant process spaces **804** managed by tenant management process space **810** for example. Invocations to such applications may be coded using PL/SOQL **834** that provides a programming language style interface extension to API **832**. Invocations to applications may be detected by one or more system processes, which manages retrieving application metadata **831** for the subscriber making the invocation and executing the metadata as an application in a virtual machine.

Each application server **800** may be communicably coupled to database systems, e.g., having access to system data **825** and tenant data **823**, via a different network connection. For example, one application server **800**$_1$ might be coupled via the network **814** (e.g., the Internet), another application server **800**$_{N-1}$ might be coupled via a direct network link, and another application server **800**$_N$ might be coupled by yet a different network connection. Transfer Control Protocol and Internet Protocol (TCP/IP) are typical protocols for communicating between application servers **800** and the database system. However, it will be apparent to one skilled in the art that other transport protocols may be used to optimize the system depending on the network interconnect used.

In certain implementations, each application server **800** is configured to handle requests for any user associated with any organization that is a tenant. Because it is desirable to be able to add and remove application servers from the server pool at any time for any reason, there is preferably no server affinity for a user and/or organization to a specific application server **800**. In one implementation, therefore, an interface system implementing a load balancing function (e.g., an F5 Big-IP load balancer) is communicably coupled between the application servers **800** and the user systems **812** to distribute requests to the application servers **800**. In one implementation, the load balancer uses a least connections algorithm to route user requests to the application servers **800**. Other examples of load balancing algorithms, such as round robin and observed response time, also may be used. For example, in certain implementations, three consecutive requests from the same user may hit three different application servers **800**, and three requests from different users may hit the same application server **800**. In this manner, system **816** is multi-tenant, in which system **816** handles storage of, and access to, different objects, data and applications across disparate users and organizations.

As an example of storage, one tenant might be a company that employs a sales force where each salesperson uses system **816** to manage their sales process. Thus, a user might maintain contact data, leads data, customer follow-up data, performance data, goals, and progress data, etc., all applicable to that user's personal sales process (e.g., in tenant data storage **822**). In an example of a MTS arrangement, since all of the data and the applications to access, view, modify, report, transmit, calculate, etc., may be maintained and accessed by a user system having nothing more than network access, the user may manage his or her sales efforts and cycles from any of many different user systems. For example, if a salesperson is visiting a customer and the customer has Internet access in their lobby, the salesperson may obtain critical updates as to that customer while waiting for the customer to arrive in the lobby.

While each user's data might be separate from other users' data regardless of the employers of each user, some data might be organization-wide data shared or accessible by a plurality of users or all of the users for a given organization that is a tenant. Thus, there might be some data structures managed by system **816** that are allocated at the tenant level while other data structures might be managed at the user level. Because an MTS might support multiple tenants including possible competitors, the MTS may have security protocols that keep data, applications, and application use separate. Also, because many tenants may opt for access to an MTS rather than maintain their own system, redundancy, up-time, and backup are additional functions that may be implemented in the MTS. In addition to user-specific data and tenant specific data, system **816** might also maintain system level data usable by multiple tenants or other data. Such system level data might include industry reports, news, postings, and the like that are sharable among tenants.

In certain implementations, user systems **812** (which may be client systems) communicate with application servers **800** to request and update system-level and tenant-level data from system **816** that may require sending one or more queries to tenant data storage **822** and/or system data storage **824**. System **816** (e.g., an application server **800** in system **816**) automatically generates one or more SQL statements (e.g., one or more SQL queries) that are designed to access the desired information. System data storage **824** may generate query plans to access the requested data from the database.

Each database may generally be viewed as a collection of objects, such as a set of logical tables, containing data fitted into predefined categories. A "table" is one representation of a data object and may be used herein to simplify the conceptual description of objects and custom objects as described herein. It is understood that "table" and "object" may be used interchangeably herein. Each table generally contains one or more data categories logically arranged as columns or fields in a viewable schema. Each row or record of a table contains an instance of data for each category defined by the fields. For example, a CRM database may include a table that describes a customer with fields for basic contact information such as name, address, phone number, fax number, etc. Another table might describe a purchase order, including fields for information such as customer, product, sale price, date, etc. In some multi-tenant database systems, standard entity tables might be provided for use by all tenants. For CRM database applications, such standard entities might include tables for Account, Contact, Lead, and Opportunity data, each containing pre-defined fields. It is understood that the word "entity" may also be used interchangeably herein with "object" and "table."

In some multi-tenant database systems, tenants may be allowed to create and store custom objects, or they may be allowed to customize standard entities or objects, for example by creating custom fields for standard objects, including custom index fields. In certain implementations, for example, all custom entity data rows are stored in a single multi-tenant physical table, which may contain multiple logical tables per organization. It is transparent to customers that their multiple "tables" are in fact stored in one large table or that their data may be stored in the same table as the data of other customers.

FIG. **9** is a diagram of a machine in the example form of a computer system, in accordance with some implementations. Machine **900** in the exemplary form of a computer system, in accordance with one implementation, within which a set of instructions, for causing the machine/computer system **900** to perform any one or more of the methodologies discussed herein, may be executed. In alternative implementations, the machine may be connected (e.g., networked) to other machines in a Local Area Network (LAN), an intranet, an extranet, or the public Internet. The machine may operate in the capacity of a server or a client machine in a client-server network environment, as a peer machine in a peer-to-peer (or distributed) network environment, as a server or series of servers within an on-demand service environment. Certain implementations of the machine may be in the form of a personal computer (PC), a tablet PC, a set-top box (STB), a Personal Digital Assistant (PDA), a cellular telephone, a web appliance, a server, a network router, switch or bridge, computing system, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines (e.g., computers) that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

The exemplary computer system **900** includes a processor **902**, a main memory **904** (e.g., read-only memory (ROM), flash memory, dynamic random access memory (DRAM) such as synchronous DRAM (SDRAM) or Rambus DRAM (RDRAM), etc., static memory such as flash memory, static random access memory (SRAM), volatile but high-data rate RAM, etc.), and a secondary memory **918** (e.g., a persistent storage device including hard disk drives and a persistent database and/or a multi-tenant database implementation), which communicate with each other via a bus **930**. Main memory **904** includes blockchain verification services or applications **923**. Other blockchain interface **925** functions can also be stored in the main memory **904**. Main memory **904** and its sub-elements are operable in conjunction with processing logic **926** and processor **902** to perform the methodologies discussed herein.

Processor **902** represents one or more general-purpose processing devices such as a microprocessor, central processing unit, or the like. More particularly, the processor **902** may be a complex instruction set computing (CISC) microprocessor, reduced instruction set computing (RISC) microprocessor, very long instruction word (VLIW) microprocessor, processor implementing other instruction sets, or processors implementing a combination of instruction sets. Processor **902** may also be one or more special-purpose processing devices such as an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a digital signal processor (DSP), network processor, or the like. Processor **1002** is configured to execute the processing logic **926** for performing the operations and functionality which is discussed herein.

The computer system **900** may further include a network interface card **908**. The computer system **900** also may include a user interface **910** (such as a video display unit, a liquid crystal display, etc.), an alphanumeric input device **912** (e.g., a keyboard), a cursor control device **914** (e.g., a mouse), and a signal generation device **916** (e.g., an integrated speaker). The computer system **900** may further include peripheral device **936** (e.g., wireless, or wired communication devices, memory devices, storage devices, audio processing devices, video processing devices, etc.).

The secondary memory **918** may include a non-transitory machine-readable storage medium or a non-transitory computer readable storage medium or a non-transitory machine-accessible storage medium **931** on which is stored one or more sets of instructions (e.g., software **922**) embodying any one or more of the methodologies or functions described herein. The software **922** may also reside, completely or at least partially, within the main memory **1004** and/or within the processor **902** during execution thereof by the computer system **900**, the main memory **904** and the processor **902** also constituting machine-readable storage media. The software **922** may further be transmitted or received over a network **920** via the network interface card **908**.

Exemplary Electronic Devices

Electronic Device and Machine-Readable Media

One or more parts of the above implementations may include software and/or a combination of software and hardware. An electronic device (also referred to as a computing device, computer, etc.) includes hardware and software, such as a set of one or more processors coupled to one or more machine-readable storage media (e.g., magnetic disks, optical disks, read only memory (ROM), Flash memory, phase change memory, solid state drives (SSDs)) to store code (which is composed of software instructions and which is sometimes referred to as computer program code or a computer program) for execution on the set of processors and/or to store data. For instance, an electronic device may include non-volatile memory (with slower read/write times, e.g., magnetic disks, optical disks, read only memory (ROM), Flash memory, phase change memory, SSDs) and volatile memory (e.g., dynamic random access memory (DRAM), static random access memory (SRAM)), where the non-volatile memory persists code/data even when the electronic device is turned off or when power is otherwise removed, and the electronic device copies that part of the code that is to be executed by the set of processors of that electronic device from the non-volatile memory into the volatile memory of that electronic device during operation because volatile memory typically has faster read/write times. As another example, an electronic device may include a non-volatile memory (e.g., phase change memory) that persists code/data when the electronic device is turned off, and that has sufficiently fast read/write times such that, rather than copying the part of the code/data to be executed into volatile memory, the code/data may be provided directly to the set of processors (e.g., loaded into a cache of the set of processors); in other words, this non-volatile memory operates as both long term storage and main memory, and thus the electronic device may have no or only a small amount of volatile memory for main memory. In addition to storing code and/or data on machine-readable storage media, typical electronic devices can transmit code and/or data over one or more machine-readable transmission media (also called a carrier) (e.g., electrical, optical, radio, acoustical or other form of propagated signals—such as carrier waves, infrared signals). For instance, typical electronic devices also include a set of one or more physical network interface(s) to establish network connections (to transmit and/or receive code and/or data using propagating signals) with other electronic devices. Thus, an electronic device may store and transmit (internally and/or with other electronic devices over a network) code and/or data with one or more machine-readable media (also referred to as computer-readable media).

Electronic devices are used for a variety of purposes. For example, an electronic device (sometimes referred to as a server electronic device) may execute code that cause it to operate as one or more servers used to provide a service to another electronic device(s) (sometimes referred to as a client electronic device, a client computing device, or a client device) that executes client software (sometimes referred to as client code or an end user client) to communicate with the service. The server and client electronic devices may be operated by users respectively in the roles of administrator (also known as an administrative user) and end user.

FIG. **10**A is a block diagram illustrating an electronic device **1000** according to some example implementations. FIG. **10**A includes hardware **1020** comprising a set of one or more processor(s) **1022**, a set of one or more network interfaces **1024** (wireless and/or wired), and non-transitory machine-readable storage media **1026** having stored therein software **1028** (which includes instructions executable by the set of one or more processor(s) **1022**). Each of the previously described end user clients and the code introspection service may be implemented in one or more electronic devices **1000**. In one implementation: 1) each of the end user clients is implemented in a separate one of the electronic devices **1000** (e.g., in user electronic devices operated by users where the software **1028** represents the software to implement end user clients to interface with the code introspection service (e.g., a web browser, a native client, a portal, a command-line interface, and/or an application program interface (API) based upon protocols such as Simple Object Access Protocol (SOAP), Representational State Transfer (REST), etc.)); 2) the code introspection service is implemented in a separate set of one or more of the electronic devices **1000** (e.g., a set of one or more server electronic devices where the software **1028** represents the software to implement the code introspection service); and 3) in operation, the electronic devices implementing the end user clients and the code introspection service would be communicatively coupled (e.g., by a network) and would establish between them (or through one or more other layers) connections for submitting queries to the code introspection service and returning filtered code information to the end user clients. Other configurations of electronic devices may be used in other implementations (e.g., an implementation in which the end user client and the code introspection service are implemented on a single electronic device **1000**).

In electronic devices that use compute virtualization, the set of one or more processor(s) **1022** typically execute software to instantiate a virtualization layer **1008** and software container(s) **1004**A-R (e.g., with operating system-level virtualization, the virtualization layer **1008** represents the kernel of an operating system (or a shim executing on a base operating system) that allows for the creation of multiple software containers **1004**A-R (representing separate user space instances and also called virtualization engines, virtual private servers, or jails) that may each be used to execute a set of one or more applications; with full virtualization, the virtualization layer **1008** represents a hypervisor (sometimes referred to as a virtual machine monitor (VMM)) or a hypervisor executing on top of a host operating system, and the software containers **1004**A-R each represent a tightly isolated form of a software container called a virtual machine that is run by the hypervisor and may include a guest operating system; with para-virtualization, an operating system or application running with a virtual machine may be aware of the presence of virtualization for optimization purposes). Again, in electronic devices where compute virtualization is used, during operation an instance of the software **1028** (illustrated as instance **1006**A) is executed within the software container **1004**A on the virtualization layer **1008**. In electronic devices where compute virtualization is not used, the instance **1006**A on top of a host operating system is executed on the "bare metal" electronic device **1000**. The instantiation of the instance **1006**A, as well as the virtualization layer **1008** and software containers **1004**A-R if implemented, are collectively referred to as software instance(s) **1002**.

Alternative implementations of an electronic device may have numerous variations from that described above. For example, customized hardware and/or accelerators might also be used in an electronic device.

Network Device

A network device (ND) is an electronic device that communicatively interconnects other electronic devices on the network (e.g., other network devices, user electronic devices, server electronic devices). Some network devices are "multiple services network devices" that provide support for multiple networking functions (e.g., routing, bridging, switching, Layer **2** aggregation, session border control, Quality of Service, and/or subscriber management), and/or provide support for multiple application services (e.g., data, voice, and video).

Exemplary Environment

FIG. **10**B is a block diagram of an environment where a code introspection service may be deployed, according to some implementations. A system **1040** includes hardware (a set of one or more electronic devices) and software to provide service(s) **1042**, including the code introspection service. The system **1040** is coupled to user electronic devices **1080**A-S over a network **1082**. The service(s) **1042** may be on-demand services that are made available to one or more of the users **1084**A-S working for one or more other organizations (sometimes referred to as outside users) so that those organizations do not need to necessarily be concerned with building and/or maintaining a system, but instead makes use of the service(s) **1042** when needed (e.g., on the demand of the users **1084**A-S). The service(s) **1042** may communication with each other and/or with one or more of the user electronic devices **1080**A-S via one or more Application Programming Interface(s) (APIs) (e.g., a Representational State Transfer (REST) API). The user electronic devices **1080**A-S are operated by users **1084**A-S.

In one implementation, the system **1040** is a multi-tenant cloud computing architecture supporting multiple services, such as a code introspection service, which can be used in conjunction with other services including a customer relationship management (CRM) service (e.g., Sales Cloud by salesforce.com, Inc.), a contracts/proposals/quotes service (e.g., Salesforce CPQ by salesforce.com, Inc.), a customer support service (e.g., Service Cloud and Field Service Lightning by salesforce.com, Inc.), a marketing service (e.g., Marketing Cloud, Salesforce DMP, and Pardot by salesforce.com, Inc.), a commerce service (e.g., Commerce Cloud Digital, Commerce Cloud Order Management, and Commerce Cloud Store by salesforce.com, Inc.), communication with external business data sources (e.g., Salesforce Connect by salesforce.com, Inc.), a productivity service (e.g., Quip by salesforce.com, Inc.), database as a service (e.g., Database.com™ by salesforce.com, Inc.), Data as a Service (DAAS) (e.g., Data.com by salesforce.com, Inc.), Platform as a Service (PAAS) (e.g., execution runtime and application (app) development tools; such as, Heroku™ Enterprise, Thunder, and Force.com® and Lightning by salesforce.com, Inc.), an analytics service (e.g., Einstein Analytics, Sales Analytics, and/or Service Analytics by salesforce.com, Inc.), a community service (e.g., Community Cloud and Chatter by salesforce.com, Inc.), an Internet of Things (IoT) service (e.g., Salesforce IoT and IoT Cloud by salesforce.com, Inc.), industry specific services (e.g., Financial Services Cloud and Health Cloud by salesforce.com, Inc.), and/or Infrastructure as a Service (IAAS) (e.g., virtual machines, servers, and/or storage). For example, system **1040** may include an application platform **1044** that enables PAAS for creating, managing, and executing one or more applications developed by the provider of the application platform **1044**, users accessing the system **1040** via one or more of user electronic devices **1080**A-S, or third-party application developers accessing the system **1040** via one or more of user electronic devices **1080**A-S.

In some implementations, one or more of the service(s) **1042** may utilize one or more multi-tenant databases **1046** for tenant data **1048**, as well as system data storage **1050** for system data **1052** accessible to system **1040**. In certain implementations, the system **1040** includes a set of one or more servers that are running on server electronic devices and that are configured to handle requests for any authorized user associated with any tenant (there is no server affinity for a user and/or tenant to a specific server). The user electronic device **1080**A-S communicate with the server(s) of system **1040** to request and update tenant-level data and system-level data hosted by system **1040**, and in response the system **1040** (e.g., one or more servers in system **1040**) automatically may generate one or more Structured Query Language (SQL) statements (e.g., one or more SQL queries) that are designed to access the desired information from the one or more multi-tenant database **1046** and/or system data storage **1050**.

In some implementations, the service(s) **1042** are implemented using virtual applications dynamically created at run time responsive to queries from the user electronic devices **1080**A-S and in accordance with metadata, including: 1) metadata that describes constructs (e.g., forms, reports, workflows, user access privileges, business logic) that are common to multiple tenants; and/or 2) metadata that is tenant specific and describes tenant specific constructs (e.g., tables, reports, dashboards, interfaces, etc.) and is stored in a multi-tenant database. To that end, the program code **1060** may be a runtime engine that materializes application data from the metadata; that is, there is a clear separation of the compiled runtime engine (also known as the system kernel), tenant data, and the metadata, which makes it possible to independently update the system kernel and tenant-specific applications and schemas, with virtually no risk of one affecting the others. Further, in one implementation, the application platform **1044** includes an application setup mechanism that supports application developers' creation and management of applications, which may be saved as metadata by save routines. Invocations to such applications, including the code introspection service, may be coded using Procedural Language/Structured Object Query Language (PL/SOQL) that provides a programming language style interface. A detailed description of some PL/SOQL language implementations is discussed in U.S. Pat. No. 7,730,478 entitled, METHOD AND SYSTEM FOR ALLOWING ACCESS TO DEVELOPED APPLICATIONS VIA A MULTI-TENANT ON-DEMAND DATABASE SERVICE, by Craig Weissman, filed Sep. 21, 2007. Invocations to applications may be detected by one or more system processes, which manages retrieving application metadata for the tenant making the invocation and executing the metadata as an application in a software container (e.g., a virtual machine).

Network **1082** may be any one or any combination of a LAN (local area network), WAN (wide area network), telephone network, wireless network, point-to-point network, star network, token ring network, hub network, or other appropriate configuration. The network may comply with one or more network protocols, including an Institute of Electrical and Electronics Engineers (IEEE) protocol, a 3rd Generation Partnership Project (3GPP) protocol, or similar wired and/or wireless protocols, and may include one or more intermediary devices for routing data between the system **1040** and the user electronic devices **1080**A-S.

Each user electronic device **1080**A-S (such as a desktop personal computer, workstation, laptop, Personal Digital Assistant (PDA), smart phone, etc.) typically includes one or more user interface devices, such as a keyboard, a mouse, a trackball, a touch pad, a touch screen, a pen or the like, for interacting with a graphical user interface (GUI) provided on a display (e.g., a monitor screen, a liquid crystal display (LCD), etc.) in conjunction with pages, forms, applications and other information provided by system **1040**. For example, the user interface device can be used to access data and applications hosted by system **1040**, and to perform searches on stored data, and otherwise allow a user **1084** to interact with various GUI pages that may be presented to a user **1084**. User electronic devices **1080**A-S might communicate with system **1040** using TCP/IP (Transfer Control Protocol and Internet Protocol) and, at a higher network level, use other networking protocols to communicate, such as Hypertext Transfer Protocol (HTTP), FTP, Andrew File System (AFS), Wireless Application Protocol (WAP), File Transfer Protocol (FTP), Network File System (NFS), an application program interface (API) based upon protocols such as Simple Object Access Protocol (SOAP), Representational State Transfer (REST), etc. In an example where HTTP is used, one or more user electronic devices **1080**A-S might include an HTTP client, commonly referred to as a "browser," for sending and receiving HTTP messages to and from server(s) of system **1040**, thus allowing users **1084** of the user electronic device **1080**A-S to access, process and view information, pages and applications available to it from system **1040** over network **1082**.

CONCLUSION

In the above description, numerous specific details such as resource partitioning/sharing/duplication implementations, types and interrelationships of system components, and logic partitioning/integration choices are set forth in order to provide a more thorough understanding. It will be appreciated, however, by one skilled in the art, that the invention may be practiced without such specific details. In other instances, control structures, logic implementations, opcodes, means to specify operands, and full software instruction sequences have not been shown in detail since

those of ordinary skill in the art, with the included descriptions, will be able to implement what is described without undue experimentation.

References in the specification to "one implementation," "an implementation," "an example implementation," etc., indicate that the implementation described may include a particular feature, structure, or characteristic, but every implementation may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same implementation. Further, when a particular feature, structure, or characteristic is described in connection with an implementation, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other implementations whether or not explicitly described.

Bracketed text and blocks with dashed borders (e.g., large dashes, small dashes, dot-dash, and dots) may be used herein to illustrate optional operations and/or structures that add additional features to some implementations. However, such notation should not be taken to mean that these are the only options or optional operations, and/or that blocks with solid borders are not optional in certain implementations.

In the following description and claims, the term "coupled," along with its derivatives, may be used. "Coupled" is used to indicate that two or more elements, which may or may not be in direct physical or electrical contact with each other, co-operate or interact with each other.

The operations in the flow diagrams are be described with reference to the exemplary implementations in the other figures. However, the operations of the flow diagrams can be performed by implementations other than those discussed with reference to the other figures, and the implementations discussed with reference to these other figures can perform operations different than those discussed with reference to the flow diagrams.

While the flow diagrams in the figures show a particular order of operations performed by certain implementations, it should be understood that such order is exemplary (e.g., alternative implementations may perform the operations in a different order, combine certain operations, overlap certain operations, etc.).

While the above description includes several exemplary implementations, those skilled in the art will recognize that the invention is not limited to the implementations described and can be practiced with modification and alteration within the spirit and scope of the appended claims. The description is thus illustrative instead of limiting.

What is claimed is:

1. A method for code introspection in a multi-tenant architecture, the method comprising:

receiving from an entity a structured query language (SQL) query for a database that facilitates code introspection, wherein the database stores symbol table data, in an SQL queryable format, generated as part of compiling code for the multi-tenant architecture;

retrieving context for the entity that sent the query;

retrieving information, from the database based on the SQL query, regarding the symbol table data;

filtering the information based on the context; and

returning the filtered information.

2. The method of claim **1**, wherein the entity is a program executing a function that sends the query.

3. The method of claim **1**, wherein the entity is a user submitting the query via a command line interface.

4. The method of claim **1**, wherein the context defines permissions for a user, organization, and tenant of the multi-tenant architecture.

5. The method of claim **1**, wherein the filtering removes one or more portions of the information that the entity lacks permissions to access.

6. The method of claim **1**, wherein the information is a symbol table generated by the compiler of the multi-tenant architecture.

7. The method of claim **1**, wherein the information is an abstract syntax tree generated by the compiler of the multi-tenant architecture.

8. A non-transitory machine-readable storage medium that provides instructions that, if executed by a processor, will cause said processor to perform operations for code introspection in a multi-tenant architecture, the operations comprising:

receiving from an entity a structured query language (SQL) query for a database that facilitates code introspection, wherein the database stores symbol table data, in an SQL queryable format, generated as part of compiling code for the multi-tenant architecture;

retrieving context for the entity that sent the query;

retrieving information, from the database based on the SQL query, regarding the symbol table data;

filtering the information based on the context; and

returning the filtered information.

9. The non-transitory machine-readable storage medium of claim **8**, wherein the entity is a program executing a function that sends the query.

10. The non-transitory machine-readable storage medium of claim **8**, wherein the entity is a user submitting the query via a command line interface.

11. The non-transitory machine-readable storage medium of claim **8**, wherein the context defines permissions for a user, organization, and tenant of the multi-tenant architecture.

12. The non-transitory machine-readable storage medium of claim **8**, wherein the filtering removes one or more portions of the information that the entity lacks permissions to access.

13. The non-transitory machine-readable storage medium of claim **8**, wherein the information is a symbol table generated by the compiler of the multi-tenant architecture.

14. The non-transitory machine-readable storage medium of claim **8**, wherein the information is an abstract syntax tree generated by the compiler of the multi-tenant architecture.

15. A computing device to execute a method for code introspection in a multi-tenant architecture, the computing device comprising:

a non-transitory machine-readable storage structure to store a database that stores information that was generated by a compiler of the multi-tenant architecture and that relates to compilation processes performed by the compiler, and a code introspection service; and

a processor coupled to the non-transitory machine-readable storage structure, the processor to execute the code introspection service, the code introspection service to:

receive from an entity a structured query language (SQL) query for a database that facilitates code introspection, wherein the database stores symbol table data, in an SQL queryable format, generated as part of compiling code for the multi-tenant architecture;

retrieve context for the entity that sent the query;

retrieving information, from the database based on the SQL query, regarding the symbol table data;

filter the information based on the context; and

return the filtered information.

16. The computing device of claim **15**, wherein the entity is a program executing a function that sends the query.

17. The computing device of claim **15**, wherein the entity is a user submitting the query via a command line interface.

18. The computing device of claim **15**, wherein the context defines permissions for a user, organization, and tenant of the multi-tenant architecture.

19. The computing device of claim **15**, wherein the filtering removes one or more portions of the information that the entity lacks permissions to access.

20. The computing device of claim **15**, wherein the information is a symbol table generated by the compiler of the multi-tenant architecture.

21. The computing device of claim **15**, wherein the information is an abstract syntax tree generated by the compiler of the multi-tenant architecture.

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